(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 July 2006 (06.07.2006)

PCT

(10) International Publication Number
WO 2006/071517 A2

(51) International Patent Classification:
B29C 47/76 (2006.01)

(21) International Application Number:
PCT/US2005/045053

(22) International Filing Date:
14 December 2005 (14.12.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/023,988 27 December 2004 (27.12.2004) US

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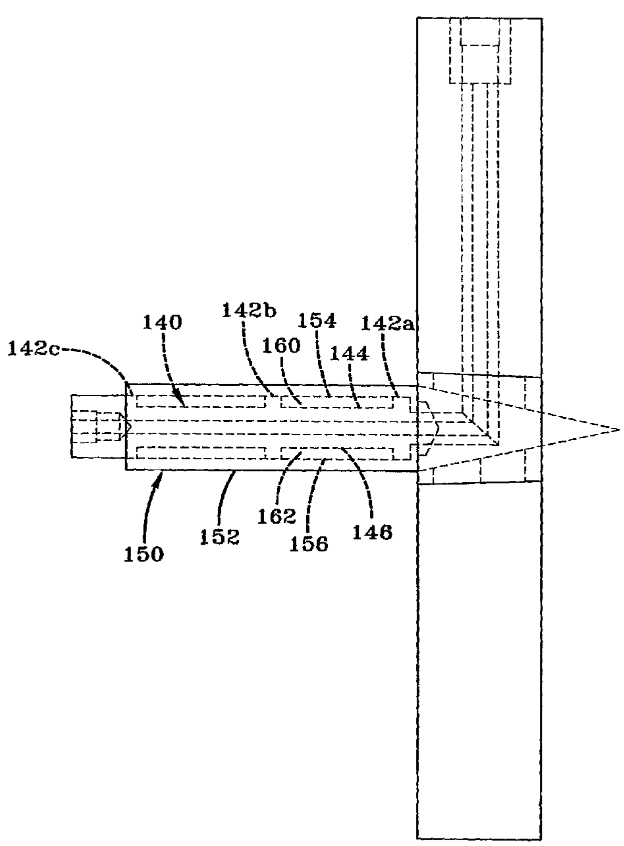
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR DIRECTING A FLUID THROUGH A DIE



(57) Abstract: A system and method for directing a fluid through a die. A transfer device for a fluid (e.g., a cooling fluid or a material) may extend through an interior of the die. The transfer device may be situated such that undesired heat transfer with other portions of the die is limited.

WO 2006/071517 A2

ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *without international search report and to be republished upon receipt of that report*

SYSTEM AND METHOD FOR DIRECTING A FLUID THROUGH A DIE

[0001] This is a continuation-in-part of U.S. Application No. 10/430,979, filed May 7, 2003, pending, which is a continuation-in-part of U.S. Application No. 10/280,735, filed October 25, 2002, pending, which is a continuation-in-part of U.S. Application No. 10/131,578, filed April 24, 2002, now U.S. Patent No. 6,637,213, which is a continuation-in-part of U.S. Application No. 10/025,432, filed December 19, 2001, now U.S. Patent No. 6,708,504, which is a continuation-in-part of U.S. Application No. 09/766,054, filed January 19, 2001, now U.S. Patent No. 6,578,368, each of which is hereby incorporated by reference in its entirety.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] The present invention relates generally to a system and method for directing a fluid through a die. One embodiment of the present invention is a system and method for cooling extruded and molded materials with a fluid that is below about 80 degrees Fahrenheit. Another embodiment of the present invention is a system and method for directing a fluid through a die, such as for cooling a product or forming a layer or portion of a product.

[0003] For several reasons, there is a need to find materials that exhibit the look and feel of natural wood. The supply of wood in the world's forests for construction and other purposes is dwindling. Consequently, the supply of wood from mature trees has become a concern in recent years, and the cost of wood has risen. As a result, several attempts have been made by others to find a suitable wood-like material.

[0004] Cellulosic/polymer composites have been developed as replacements for all-natural wood, particle board, wafer board, and other similar materials. For example, U.S. Patent Nos. 3,908,902, 4,091,153, 4,686,251, 4,708,623, 5,002,713, 5,055,247, 5,087,400, 5,151,238, 6,011,091, and 6,103,791 relate to processes and/or compositions for making wood replacement products. As compared to natural woods, cellulosic/polymer composites offer superior resistance to wear and tear. In addition, cellulosic/polymer composites have enhanced resistance to moisture, and it is well known that the retention of moisture is a primary cause of the warping, splintering, and discoloration of natural woods. Moreover, cellulosic/polymer composites may be sawed, sanded, shaped, turned, fastened, and finished in the same manner as natural woods. Therefore, cellulosic/polymer composites are commonly used for applications such as interior and exterior decorative house moldings, picture frames, furniture, porch decks, deck railings, window moldings, window components, door components, roofing structures, building siding, and other suitable indoor and outdoor items. However, many attempts to make products from cellulosic/polymer composite materials have failed due to poor or improper manufacturing techniques.

[0005] In one embodiment of the present invention, a product or article may be manufactured by a desired technique such as, but not limited to, extrusion, compression molding, injection molding, or other similar, suitable, or conventional manufacturing techniques. The product is then cooled by subjecting it to a cooling fluid including, but not limited to, direct contact with a liquid cryogenic fluid. The present invention can be used alone or in conjunction with other known or later developed cooling methods. Accordingly, the present invention can more thoroughly and efficiently cool the manufactured product or article to a desired level. This can

lead to faster production times as well as a product having improved structural, physical, and aesthetic characteristics.

[0006] In addition to cooling extruded or molded materials, the present invention may also be used in other types of manufacturing techniques in which the output or material must be cooled from a heated state. The present invention includes a system and method for cooling synthetic wood composite materials including, but not limited to, cellulosic-filled plastic composites. In addition, the present invention may also be used to cool other types of pure or mixed materials including, but not limited to, plastics, polymers, foamed plastics, plastic compositions, inorganic-filled plastic compositions, metals, metallic compositions, alloys, mixtures including any of the aforementioned materials, and other similar, conventional, or suitable materials that need to be cooled after being processed. For instance, the present invention may be used to cool polyvinyl chloride (PVC) products and products made from other plastics.

[0007] The present invention also includes a system and method for directing a fluid through a die. In one embodiment, a fluid may be directed through a die for cooling purposes. In another embodiment, a fluid may be directed through a die for forming a layer or portion of a product. More particularly, a fluid may be directed through a die to form an external or core layer of a product from a foamed or unfoamed material including, but not limited to, a cellulosic-filled plastic composite. For example, the present invention includes a system and method for through the die foaming of extruded products. For instance, a core foam layer may be formed using an exemplary system and method of the present invention. Like the other embodiments of the present invention, this embodiment may be used with other types of pure or mixed materials including, but not limited to, plastics, polymers,

foamed plastics, plastic compositions, inorganic-filled plastic compositions, metals, metallic compositions, alloys, mixtures including any of the aforementioned materials, and other similar, conventional, or suitable materials that may be processed through a die. For instance, the present invention may be used to manufacture polyvinyl chloride (PVC) products and products made from other plastics.

[0008] In addition to the novel features and advantages mentioned above, other objects and advantages of the present invention will be readily apparent from the following descriptions of the drawings and exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a perspective view of an extrudate.

[0010] Figure 2 is a perspective view of an extrusion die showing an exemplary location of a nozzle.

[0011] Figure 3 is a schematic view of one exemplary embodiment of a system implementing the present invention.

[0012] Figure 4 is a partial cross sectional view along the line A-A of Figure 3.

[0013] Figure 5 is a partial elevational view of another exemplary embodiment of a system of the present invention.

[0014] Figure 6 shows a sectioned schematic of an extruder line used in accordance with the practice of one exemplary embodiment of the present invention.

[0015] Figure 7 is a cross sectional view from a lateral side angle of an exemplary die of the present invention.

[0016] Figure 8 is a cross sectional view from a top side angle of the die of Figure 7.

[0017] Figure 9 is a cross sectional view from an exit side angle of the die of Figure 7.

[0018] Figure 10 is a cross sectional view from a lateral side angle of an exemplary die of the present invention that includes a baffle.

[0019] Figure 11 is a cross sectional view from a lateral side angle of another exemplary die of the present invention that includes a baffle.

[0020] Figure 12 is a schematic view of an exemplary embodiment of a system of the present invention that enables direct cooling by a liquid cryogenic fluid.

[0021] Figure 13 is a side elevational view of an exemplary embodiment of a transfer device of the present invention.

[0022] Figure 14 is a partial view of a die showing exemplary embodiments of a mandrel and a transfer device of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENT(S)

[0023] The present invention is directed to a system and method for cooling manufactured articles or products. The present invention is also directed to a system and method for directing a fluid through a die. It is not intended to limit the present invention to particular manufacturing techniques or particular materials. The present invention may be used in conjunction with articles or products made by a variety of different manufacturing techniques. Examples of manufacturing techniques that may utilize the present invention include, but are not limited to, extrusion (including co-extrusion), compression molding, injection molding, and other known, similar, or conventional techniques for manufacturing products or articles from plastic, wood, metal, mixtures of these materials, or other materials used to make products.

[0024] The present invention is particularly useful with plastics, polymers, and cellulosic/polymer composite materials that have been extruded or molded. The materials that may be used to make cellulosic/polymer composites include, but are not limited to, cellulosic fillers, polymers, plastics, thermoplastics, inorganic fillers, cross-linking agents, lubricants, process aids, stabilizers, accelerators, inhibitors, enhancers, compatibilizers, blowing agents, foaming agents, thermosetting materials, and other similar, suitable, or conventional materials. Examples of cellulosic fillers include sawdust, newspapers, alfalfa, wheat pulp, wood chips, wood fibers, wood particles, ground wood, wood flour, wood flakes, wood veneers, wood laminates, paper, cardboard, straw, cotton, rice hulls, coconut shells, peanut shells, bagass, plant fibers, bamboo fiber, palm fiber, kenaf, flax, and other similar materials. In addition to PVC, examples of polymers include multilayer films, high density polyethylene (HDPE), polypropylene (PP), low density polyethylene (LDPE), chlorinated polyvinyl chloride (CPVC), acrylonitrile butadiene styrene (ABS), ethyl-vinyl acetate, other similar copolymers, other similar, suitable, or conventional thermoplastic materials, and formulations that incorporate any of the aforementioned polymers. Examples of inorganic fillers include talc, calcium carbonate, kaolin clay, magnesium oxide, titanium dioxide, silica, mica, barium sulfate, acrylics, and other similar, suitable, or conventional materials. Examples of thermosetting materials include polyurethanes, such as isocyanates, phenolic resins, unsaturated polyesters, epoxy resins, and other similar, suitable, or conventional materials. Combinations of the aforementioned materials are also examples of thermosetting materials. Examples of lubricants include zinc stearate, calcium stearate, esters, amide wax, paraffin wax, ethylene bis-stearamide, and other similar, suitable, or conventional materials. Examples of stabilizers include tin stabilizers, lead and metal soaps such

as barium, cadmium, and zinc, and other similar, suitable, or conventional materials. In addition, examples of process aids include acrylic modifiers and other similar, suitable, or conventional materials.

[0025] Figure **1** shows one example of an extrudate **100** that may be cooled by the present invention. The extrudate **100** includes an exterior surface **102**, a hollow **104**, an interior surface **106**, and two ends **108**. The exterior surface **102** may be cooled by a traditional method such as using a warm water bath or water mist. However, the interior surface **106** may not be sufficiently cooled by many traditional methods because the surface may not be available for contact with the cooling medium. The interior surface **106** defines the boundary of the hollow **104**. It should be recognized that a product may have a plurality of hollows. The interior surface **106** may be accessed from either end **108**. The interior surface **106** may not be cooled to a desired level within a desired amount of time by externally applied coolants.

[0026] In the present invention, a fluid may be directed into the hollow **104**. For example, a fluid may be directed into the hollow **104** for cooling purposes. For another example, a fluid may be directed into the hollow **104** to form another portion or layer of the product **100**. For instance, a fluid such as a pure or mixed material may be used to partially or completely fill the hollow **104**. Examples of pure or mixed materials include, but are not limited to, plastics, polymers, foamed plastics, plastic compositions, cellulosic-filled plastic compositions, inorganic-filled plastic compositions, metals, metallic compositions, alloys, mixtures including any of the aforementioned materials, and other similar, conventional, or suitable materials. The fluid may be similar or dissimilar to the material used to form the exterior surface **102**. For instance, the fluid and the material used to form the exterior

surface **102** may consist of the same ingredients, but in different amounts. Alternatively, the fluid and the material used to form the exterior surface **102** may consist of at least one different ingredient. Some examples may be useful to illustrate this point. One example of a product that may benefit from the present invention has a foamed or unfoamed plastic layer that is bonded to another foamed or unfoamed plastic layer. Another example of a product that may benefit from the present invention has a foamed or unfoamed plastic composite layer that is bonded to another foamed or unfoamed plastic composite layer. Still another example of a product that may be benefit from the present invention has a foamed or unfoamed plastic composite layer that is bonded to a foamed or unfoamed plastic layer. Of course, many other embodiments are possible and within the scope of the present invention.

[0027] Regardless of the type of fluid, the fluid may be directed into the hollow **104** via an in-line system or a system that is not in-line. In one embodiment, the present invention may be used to provide improved cooling of a product. In another embodiment in which a fluid forms a layer or portion of a product, the present invention may be used to reduce the weight and/or material cost of a product or to improve the physical characteristics of a product. For example, a foamed plastic may be used to form a layer or portion (e.g., a core layer) of a product that would otherwise be entirely formed of an unfoamed plastic. Another possible benefit is that the fluid (such as a fluid that forms a core layer) may help to maintain the integrity of a profile as it is processed through a sizing system. In addition, an in-line system may be more time and cost efficient.

[0028] Figure **2** shows one example of an extrusion die **200** adapted with the present invention. The extrusion die **200** defines the cross section of the extrudate

by the shape of the profile form/flow channel **206**. Hollows in the cross section of the extrudate may be formed with a standing core **202**. The standing core **202** is fitted with a spout or nozzle **204**. The nozzle **204** may be adapted to connect with a source of the cooling fluid (not shown). Alternatively, the nozzle **204** may be adapted to connect with a source of a fluid for forming a layer or portion of the resulting product. The nozzle **204** may be oriented to spray or otherwise release the fluid into the hollow formed in the extrudate cross section by the standing core **202**. The nozzle **204** may be recessed from, even with, or extend away from the face of the die **200**. In an embodiment in which the nozzle **204** extends away from the face of the die **200**, the length of the extension may be any desired distance. The extension may also be referred to as a dispensing wand.

[0029] Figure **3** shows one example of a system **300** that may utilize the present invention. The system **300** includes an extruder **302** and an extruder **304**. In this example, a crosshead die **306** puts a cap layer from the extruder **304** on the material extruded by the extruder **302**. A container **308** may be used to hold a cooling fluid of the present invention. The fluid is used to cool the extruded product or article **312** after it exits the die **306**. In this embodiment, a valve is used to control the release of gas, e.g., vapor, from the fluid. A hose, conduit, tube, or any other suitable transfer device **310** may be used to direct the gas from the container **308** to the desired location for cooling the extruded product **312**. The transfer device **310** may be formed by one integral component or a plurality of interconnected components. For instance, a portion of the transfer device **310** may be a passage through the die **306**. In this example, the transfer device **310** extends through the die **306** so that the gas is released in the hollow of the extruded product **312** after it exits the die **306**. In this manner, the present invention can provide efficient and

thorough cooling of the extruded product **312**. Moreover, the extruded product **312** may be further introduced into a liquid bath **314**, a spray mist chamber **316**, and/or any other desired cooling system to achieve additional cooling of the extruded product **312** if desired. Examples of the liquid bath **314** and the spray mist chamber **316** are provided in U.S. Patent No. 5,827,462.

[0030] Depending on the type of cooling fluid and the desired expulsion rate of the cooling fluid, the container **308** may be pressurized. The container **308** may be connected to a compressor, e.g., an air compressor or any other similar, suitable, or conventional compressing device, in order to maintain the desired pressure in the container **308**. Additionally, the container **308** may be in fluid communication with a blower or a pump to obtain the desired expulsion rate of the cooling fluid from the container **308**. A blower in fluid communication with the container **308** may also be utilized to accelerate the cooling fluid to a desired velocity after it has been expelled.

[0031] Figure **4** is a cross section view along the line **A-A** of Figure **3**. The extruded product **312** includes a cap layer **404**. The transfer device **310** may extend through the die **306** to a nozzle **406** that releases gas from the cooling fluid into a hollow of the extruded product **312**. In this instance, gas vapor **402** permeates through the hollow of the extruded product **312**, thereby providing much improved cooling of the extruded product **312**. In fact, the inventors have surprisingly discovered that using the present invention to inject the cooling fluid into a hollow portion of a product may be sufficient to thoroughly cool the entire product, i.e., the inside and the outside of the product. As a result, the present invention may eliminate the need to provide another cooling system to cool the outer surface of the product.

[0032] It should be recognized that Figures **3** and **4** are merely one example of a manufacturing system that may utilize the present invention. As noted above, the present invention may be used in any manufacturing system in which the processed material needs to be cooled to a desired level. For example, the present invention may be used in an extrusion system consisting of a single extruder that is in-line with a die. Also, the present invention may be used to cool any type of material including, but not limited to, injection molded materials and compression molded materials.

[0033] In addition, it should be recognized that the system **300** shown in Figure **3** may be adapted for use with another fluid that may form a layer or portion of the resulting product. For example, another extruder may be in fluid communication with the die **306** for adding another layer or portion of the resulting product. The extruder may be connected to the die **306** in a manner similar to extruder **302** and extruder **304**. If desired, the extruder may be substituted for the container **308** and the transfer device **310**. For instance, with reference to Figure **4**, a fluid for forming a core layer (instead of a cooling fluid) may be dispensed from the nozzle **406** into the hollow. However, it should be recognized that this embodiment of the present invention may also be used in combination with the cooling embodiment of the present invention. For example, the fluid may form a layer or portion of the product other than a core layer, or the fluid may not completely fill a hollow portion of the product.

[0034] In addition, it should be recognized that the cooling fluid of the present invention may be expelled elsewhere relative to the manufactured product (i.e., other than in a hollow portion of the product). For example, Figure **5** shows an embodiment in which the gas vapor **500** is dispersed by the transfer device **502** onto

the exterior of the product **504**. The present invention also includes dispersing multiple streams of the cooling fluid onto the same or different portions of the manufactured product. For instance, flows of the cooling fluid may be simultaneously dispersed onto the exterior and interior surfaces of the manufactured product.

[0035] Turning to Figure **6**, this Figure shows a sectioned schematic of an extruder line **600** used in accordance with the practice of one embodiment of the present invention. Figure **6** shows an extruder line **600** which includes co-extrusion apparatus **602**. Co-extrusion apparatus **602** includes insulated transport tube **604** that is adapted to carry cooling fluid **606**. Alternatively, the transport tube **604** may be adapted to carry a fluid for forming a layer or portion of the product. The cooling fluid **606** may be gas that may be delivered from a supply of cryogenic fluid. Co-extrusion apparatus **602** also includes a cross head extruder **608** which is adapted to prepare the thermoplastic material **610** for extrusion through a die which may form a hollow, rectangular profile and urges it along longitudinal direction **612**. Further layers of thermoplastic material such as layer **614** may be added through the use of additional extruders such as extruder **616**. Such additional layers of thermoplastic material may include layers of material with specific characteristics for exterior use, such as fluoropolymers and PVC having greater or lesser durability and resistance to changes in aesthetic appearance resulting from exposure to weather and environmental/atmospheric conditions, as dictated by the desired end user. The thermoplastic material **610** is formed by the forming die **618** into the desired final shape, such as a rectangular cross-section. The cooling fluid **606** permeates through the hollow space created in thermoplastic material **610**. The cooling fluid **606** may be at a significantly lower temperature than the surrounding thermoplastic

material **610**. The cooling fluid **606** cools the thermoplastic material **610**, assisting the thermoplastic material to "skin" or solidify.

[0036] Figures **7** through **9** show a cross sectional view of one example of a die **700** that is configured to be in-line with an extruder. Extruded material flows through the die in the direction indicated by arrow **702**. In this example, the resultant extrudate **704** defines three hollow portions that are separated by webs **706** and **708**. A fluid enters the die **700** through passages **710**. The fluid entering through passages **710** may be a cooling fluid or a fluid for partially or completely filling the hollow portions of the extrudate **704**. In some embodiments, it should be recognized that a tube, conduit, or any other type of transfer device may extend through the passages **710** for directing the flow of the fluid through the passages **710**. The fluid exits the die **700** through passages **710** in the direction indicated by arrows **712**. In such an embodiment, the passages **710** intersect the path of flow of the extruded material that forms the extrudate **704**. In other words, the passages **710** intersect the flow channel in the die **700**.

[0037] The die **700** may be heated to a sufficient level to facilitate extrusion and limit premature curing of the extrudate in the die **700**. In this example of an in-line system, the passages **710** actually extend through the die **700**, intersecting the path of flow of the extruded material that forms extrudate **704**. In some embodiments, it may be preferable to limit cooling of the die **700** by a cooling fluid in the passages **710**. In other embodiments, a fluid in the passages **710** that is used fill the hollow portions may be processed more effectively at a different temperature (e.g., a higher or lower temperature) than the material used to form the extrudate **704**. Accordingly, the passages **710** may be insulated by a suitable material. For example, the passages **710** may be lined with ceramic insulation, putty ceramics, or

any other similar, suitable, or conventional insulating material in order to limit undesired heat transfer by the die **700**. In fact, it should be recognized that the transfer device for the fluid in any type of embodiment may be insulated in order to limit undesired cooling or heating of surrounding items.

[0038] As best seen in the example of Figure **9**, the passages **710** may be substantially surrounded by die material **714** even where the passages **710** intersect the path of flow of the extruded material that forms extrudate **704**. In this manner, direct contact in the die **700** between the extruded material that forms extrudate **704** and the passages **710** may be avoided, if desired. The die material **714** surrounding the passages **710** may be heated to facilitate the extrusion process. Also, air gaps may be provided between the die material **714** and the passages **710** for additional insulation.

[0039] Figures **13** and **14** show an example of a transfer device **140** that may be useful for lining a passage and transferring a fluid through the interior of a die. Unless expressly stated otherwise, it is not intended to limit the type of fluid that may be transferred through the transfer device **140**. For example, the fluid may be a cooling fluid or a material that forms a product. It is also not intended to limit the transfer device **140** to any particular shape or other dimensions unless expressly stated otherwise. For instance, the transfer device may be a hose, tube, conduit, or any other type of device suitable for transferring a fluid. In addition, the transfer device **140** may have any suitable cross-sectional shape. For example, an exemplary embodiment of the transfer device **140** may be a right circular cylinder, a curved conduit, or any other suitable shape. Furthermore, it is not intended to limit the type of material from which the transfer device **140** may be made unless expressly stated otherwise. As previously indicated, an exemplary embodiment of

the transfer device **140** may be comprised of an insulating material (e.g., ceramic material). However, in other embodiments, it should be recognized that the transfer device **140** may be comprised of any of a variety of other suitable materials including, but not limited to, non-insulating materials (e.g., steel).

[0040] The transfer device **140** may be adapted to extend through the interior of a die. Figure **14** is a partial view of an exemplary die assembly in which transfer device **140** is situated in the interior **150** of the die assembly. In particular, the transfer device **140** is situated in a mandrel **152** in the interior **150** of the die assembly. Some other portions of the die assembly are not shown in order to more clearly illustrate the present invention. Such as in the other examples, the transfer device **140** may intersect a flow channel that is adapted to transfer a material through the die.

[0041] At least one portion of the transfer device **140** is adapted to be displaced from an interior portion of the die. The resulting separation or gap between the transfer device **140** and the interior portion of the die may be filled by air or another insulating material (e.g., a foam insulating material). As noted earlier, an air gap may help to reduce heat transfer from the interior portion of the die to the transfer device **140**, or vice versa. In this example, the transfer device **140** includes at least one spacer. In particular, this exemplary embodiment of the transfer device **140** includes spacer **142a** (which is located at an intermediate portion of transfer device **140**), spacer **142b** (which is located at an intermediate portion of transfer device **140**), and spacer **142c** (which is located at an exit end portion of the transfer device **140**). A spacer may have any configuration suitable to displace an adjacent side portion of the transfer device **140** from the interior portion of the die. For example, a spacer may be a flange, a rim, a rib, a leg, a spoke, or any other similar

or suitable structure, component, or projection for creating the aforementioned displacement. In this example, each of spacers **142a**, **142b**, and **142c** are integral to the transfer device **140**. In addition, the spacers **142a**, **142b**, and **142c** extend completely around the periphery of the transfer device **140** in this embodiment. However, in other embodiments of the present invention, a spacer may not be integral, or a spacer may not extend completely around the periphery of the transfer device. Figure **14** illustrates how a spacer or spacers may help to displace a side portion of this exemplary transfer device **140** from an interior portion of the die. For example, side portion **144** is adjacent to spacer **142a** and spacer **142b**, and side portion **146** is also adjacent to spacer **142a** and spacer **142b**. Spacers **142a** and **142b** substantially abut interior portion **154** and interior portion **156**. As a result, side portions **144** and **146** do not substantially abut the interior portion **154** or interior portion **156**, thereby creating air gap **160** and air gap **162** between spacer **142a** and **142b**. In this example, air gap **160** and air gap **162** are connected such that the air gap actually extends completely around the periphery of the transfer device **140** for optimum insulation. However, it should be understood that an air gap may not extend completely around the periphery of a transfer device in other embodiments of the present invention.

[0042] A transfer device may be displaced from the interior portion of the die in any other suitable way in the present invention. For example, a transfer device may be curved. As a result, certain portions of the transfer device may substantially abut the interior portion of the die while other portions of the transfer device may be displaced from the interior portion of the die. For another example, the entire transfer device may be displaced from (i.e., not abut) the interior portion of the die in the present invention.

[0043] Any desired cooling fluid may be used in the present invention. In one exemplary embodiment, the cooling fluid, e.g., gas or liquid, may have a temperature below about 80 degrees Fahrenheit, more preferably below about 68 degrees Fahrenheit, still more preferably below about 32 degrees Fahrenheit, even more preferably below about minus 100 degrees Fahrenheit. On the other hand, the temperature may be above about minus 325 degrees Fahrenheit, more preferably above about minus 300 degrees Fahrenheit, still more preferably above about minus 275 degrees Fahrenheit, even more preferably above about minus 250 degrees Fahrenheit. However, in some embodiments of the present invention, the cooling fluid may be above about 80 degrees Fahrenheit or below about minus 325 degrees Fahrenheit. Examples of the cooling fluid are air and water. Another example of the cooling fluid is gas or vapor that is produced from a cryogenic fluid. For instance, a cryogenic fluid may have a temperature below about minus 250 degrees Fahrenheit. Examples of cryogenic fluids include, but are not limited to, liquid oxygen, liquid nitrogen, liquid neon, liquid hydrogen, liquid helium, and other similar, suitable, or conventional cryogenic fluids.

[0044] In addition to the temperature, the velocity of the cooling fluid may also impact its effectiveness. By selecting a suitable velocity and temperature of the cooling fluid, the inventors have discovered that an entire product can be thoroughly cooled just by injecting the cooling fluid into a hollow portion of the product. The velocity of the cooling fluid may be greater than about 10 miles per hour, more preferably greater than about 40 miles per hour, and it may be less than about 100 miles per hour, more preferably less than about 50 miles per hour. However, it should be recognized that the velocity of the cooling fluid may be less than about 10 miles per hour or greater than about 100 miles per hour in some embodiments.

[0045] The efficiency and effectiveness of the present invention may be further increased by diverting the flow of the fluid (e.g., a cooling fluid or a fluid that forms a layer or portion of the resulting product) toward the surface of the extruded product as it exits the die. By concentrating a cooling fluid on a surface of the extrudate, the desired amount of cooling may occur more quickly resulting in the use of less cooling fluid as compared to non-diversion methods. Moreover, the increased cooling efficiency enables the use of warmer cooling fluids and a reduction in the velocity of the cooling fluid as compared to non-diversion methods. For example, this embodiment of the present invention may be particularly useful if it is desired to use a cooling fluid that is warmer than about 80 degrees Fahrenheit. However, it should be recognized that, in many embodiments, it may be desirable to use a cooling fluid below about 80 degrees Fahrenheit for optimal cooling efficiency. On the other hand, in the case of a fluid that is used to form a layer or portion of the resulting product, the diversion of the fluid toward a surface of the extruded product as it exits the die may facilitate the formation of the desired end product.

[0046] Figure **10** shows one example of a die that is adapted to divert a fluid toward a surface of an extruded project. The die **800** of this embodiment may include any of the optional or preferred features of the die **700** shown in Figures **7** through **9**. The fluid may enter the die **800** through a passage **810**. A baffle **820** is in fluid communication with the passage **810** such that it receives the fluid. The baffle **820** is adapted to then divert the flow of the fluid such that it is directed to a desired surface of the extrudate. By directing a cooling fluid toward a surface of the extrudate, the baffle **820** may also create a more turbulent flow of the cooling fluid (as compared to a straight line flow that is not directed toward a surface of the extrudate) which further enhances the efficiency of the cooling process. The baffle

820 may be any device or structure that is suitable for diverting the flow of the fluid to the desired location (e.g., an interior or exterior surface of a product). In this particular example, the baffle **820** is adapted to divert the fluid in the direction of arrows **830** toward an interior surface of a hollow portion of the extrudate. For this purpose, the baffle **820** includes an inner conical portion **840** that forces the fluid in the direction of arrows **830**.

[0047] Figure **10** shows one example of a design of a baffle **820**. It should be recognized that the design of a baffle of the present invention may vary so as to divert the fluid in the desired direction. Of course, the desired direction will vary according to the type of product being extruded and the location of the baffle relative to the extruded product.

[0048] The baffle **820** may be placed in fluid communication with the passage **810** in any suitable manner. In the example of Figure **10**, the baffle **820** is secured to an end portion of a conduit **850** that extends through the passage **810**. The baffle **820** may be secured to the end portion of the conduit **850** in any desired manner. For example, the baffle **820** may be threaded, i.e., screwed, onto the end portion of the conduit **850**. For other examples, the baffle **820** may be secured to the conduit **850** using other mechanical means (e.g., screws, pins, and other types of mechanical fastening devices) and/or adhesives. As previously noted, the conduit **850** may be insulated. The baffle **820** may also be insulated, if desired. The baffle **820** is offset from the heated portion **860** of the die **800** in this particular example. Optionally, there may be an insulated layer **870** on an exit end of the die **800**. The insulated layer **870** may be useful to prevent a cooling fluid from cooling the heated portion **860** of the die **800**.

[0049] Figure **11** shows another example of a die which may include any of the optional or preferred features of the other embodiments of the present invention. In this embodiment, the die **900** includes a passage **910** that is in fluid communication with the baffle **920**. The baffle **920** is not offset from the heated portion **930** of the die **900** in this example. In order to limit undesired heat transfer from or to the heated portion **930**, it may be preferred to use an insulated baffle **920** or otherwise provide a layer of insulation between the baffle **920** and the heated portion **930**. As in the previous example, the baffle **920** may be connected to a conduit **940** that lines that passage **910**. It should also be recognized that the baffle **920** may be placed in fluid communication with the passage **910** in any other suitable manner. For example, the baffle **920** may have a threaded connection with the heated portion **930**. In other examples, the baffle **920** may be connected to the heated portion **930** using other mechanical means (e.g., screws, pins, and other types of mechanical fastening devices) and/or adhesives. As in the previous example, an exit end of the die **900** may include a layer of insulation **950**.

[0050] The inventors have also made the surprising and significant discovery that the efficiency and efficacy of the manufacturing process may be improved by placing a liquid cryogenic fluid in direct contact with the material to be cooled. As a result, the rate of output may be increased, thereby decreasing the unit cost of the manufactured product. In addition, the inventors have discovered that the more rapid cooling providing by direct contact with a liquid cryogenic fluid may improve the structural characteristics of the manufactured product, especially in the case of foam products. In particular, the rapid removal of the heat may help to maintain the desired foam structure.

[0051] Figure **12** shows one example of a system that enables direct contact of the material with the liquid cryogenic fluid. System **120** may include a die **122** which is adapted to receive material from a piece of processing equipment, e.g., an extruder. Optionally, a sizer **124** may be in fluid communication with the die **122**. One example of a sizer **124** is a vacuum sizer. After the material exits the die **122** and, optionally, sizer **124**, the material enters a bath **126** of liquid cryogenic fluid. In the bath **126**, the material comes into direct contact with the liquid cryogenic fluid. The duration of the contact may vary according to the particular material, manufacturing process, and degree of cooling that is desired. Nevertheless, it should be recognized that just a brief period of contact (e.g., mere seconds) may provide a significant of degree of heat removal. Depending on the material, overexposure to the liquid cryogenic fluid may eventually have a negative impact on the manufactured product.

[0052] The features and physical dimensions of the bath **126** may be selected taking into consideration the minimum length of material needed for a specific application, the line speed, the desired amount of heat removal, and other factors relevant to the safety, maintenance, and performance of the system **120**. In one exemplary embodiment, the bath **126** may include at least one sizing component (i.e., sizer or sizing box) **128**. A sizing component **128** may be partially or totally submersed in the liquid cryogenic fluid during operation of the system **120**. The bath **126** may also be equipped with suitable safety and maintenance features. For example, the bath **126** may have a cover **130** to facilitate maintenance of the bath **126**. Additionally, the bath **126** may be dual-walled and insulated, and the bath **126** may include a suitable exhaust system.

[0053] The bath **126** may include a level of liquid cryogenic fluid sufficient to partially or totally submerse the material to be cooled. For instance, the bath **126** may include a level of liquid cryogenic fluid sufficient to directly contact one portion of the material to be cooled while another portion does not come into contact with the liquid cryogenic fluid. Moreover, it should be recognized that the liquid cryogenic fluid may be transferred into and out of the bath **126** based on the operational status of the system **120**. For example, the system **120** may also include a pump **132** and a holding tank **134**. The pump **132** may transfer the liquid cryogenic fluid to the bath **126** from the tank **134** approximately when the particular manufacturing process (e.g., extrusion) is initiated or at any other suitable time such that there is a desired amount of liquid cryogenic fluid in the bath **126**. Furthermore, the pump **132** may transfer the liquid cryogenic fluid back to the tank **134** after the manufacturing process (e.g., extrusion) is complete or at any other suitable time. The tank **134** may be equipped with any suitable safety and maintenance features including, but not limited to, those included on the bath **126**. Additionally, it should be recognized that a suitable safety interlock system may be included to prohibit undesired transfer of the liquid cryogenic fluid between the bath **126** and the tank **134**.

[0054] At least one additional cooling system **136** may be included subsequent to the bath **126**. Examples of a cooling system **136** include, but are not limited to, a water bath, a spray mist, air flow, another cooling system as described herein, or any other conventional or new cooling system. Additionally, it should be noted that a cooling system **136** (or additional manufacturing equipment) may be included prior to the bath **126** without departing from the scope of the present invention.

[0055] As mentioned above, many significant advantages may be achieved by placing the material to be cooled in direct contact with liquid cryogenic fluid. In addition to cooling extruded products, the present invention may be used to cool products made by any other methods including, but not limited to, compression molded products and injection molded products. Regardless of the manufacturing method, the output rate may be increased and the unit cost may be decreased due to the dramatic improvement in cooling efficiency. Also, the capital cost of an exemplary system of the present invention may be reduced as compared to conventional gas cooling systems which require some gas velocity. In addition, the increased cooling efficiency may allow shorter manufacturing lines, thereby further reducing the manufacturing cost.

[0056] A variety of products may benefit from the present invention. Examples of products that may benefit the present invention include, but are not limited to, fence components, furniture components, cabinet components, storage device components, lawn edging components, flower box components, floor components, baseboards, roof components, wall covering components, siding components, basement floor components, basement wall covering components, interior and exterior decorative house molding components, crown molding components, chair rail components, picture frame components, deck components, railing components, window molding components, window components, window frames, lineals, door components, door frames, door moldings, boards, and other suitable indoor and outdoor items.

[0057] Any embodiment of the present invention may include any of the optional or preferred features of the other embodiments of the present invention. The exemplary embodiments herein disclosed are not intended to be exhaustive or

to unnecessarily limit the scope of the invention. The exemplary embodiments were chosen and described in order to explain the principles of the present invention so that others skilled in the art may practice the invention. Having shown and described exemplary embodiments of the present invention, those skilled in the art will realize that many variations and modifications may be made to affect the described invention. Many of those variations and modifications will provide the same result and fall within the spirit of the claimed invention. It is the intention, therefore, to limit the invention only as indicated by the scope of the claims.

WHAT IS CLAIMED IS:

1. A die comprising:

a transfer device adapted to transfer a fluid, said transfer device comprising a spacer and an adjacent portion to said spacer, said spacer and said adjacent portion situated in an interior of said die;

wherein said spacer substantially abuts an interior portion of said die such that said adjacent portion of said transfer device does not substantially abut said interior potion of said die.

2. The die of claim 1 wherein said transfer device is a tube.

3. The die of claim 1 wherein said transfer device has a circular cross section.

4. The die of claim 1 wherein said transfer device is comprised of an insulating material.

5. The die of claim 1 wherein said transfer device is comprised of a ceramic material.

6. The die of claim 1 further comprising:

a flow channel through said die, said flow channel adapted to transfer a material;

wherein said transfer device intersects said flow channel.

7. The die of claim 1 wherein said spacer is at an exit end portion of said transfer device.

8. The die of claim 1 wherein said spacer is at an intermediate portion of said transfer device.

9. The die of claim 1 further comprising:

a second spacer substantially abutting said interior portion of said die;

wherein said adjacent portion is situated between said spacers.

10. A die comprising:

a transfer device adapted to transfer a fluid, said transfer device having a side portion situated in an interior of said die;

wherein said side portion is displaced from an interior portion of said die.

11. The die of claim 10 wherein said transfer device is a tube.

12. The die of claim 10 wherein said transfer device has a circular cross section.

13. The die of claim 10 wherein said transfer device is comprised of an insulating material.

14. The die of claim 10 wherein said transfer device is comprised of a ceramic material.

15. The die of claim 10 further comprising:

a flow channel through said die, said flow channel adapted to transfer a material;

wherein said transfer device intersects said flow channel.

16. A die comprising:

a transfer device adapted to transfer a fluid, said transfer device situated in an interior of said die;

wherein there is an air gap between said transfer device and an interior portion of said die.

17. The die of claim 16 wherein said transfer device is a tube.

18. The die of claim 16 wherein said transfer device has a circular cross section.

19. The die of claim 16 wherein said transfer device is comprised of an insulating material.

20. The die of claim 16 wherein said transfer device is comprised of a ceramic material.

21. The die of claim 16 further comprising:

a flow channel through said die, said flow channel adapted to transfer a material;

wherein said transfer device intersects said flow channel.

22. The die of claim 16 wherein said air gap extends around the entire periphery of said transfer device.

23. The die of claim 16 further comprising:

a first spacer substantially abutting said interior portion of said die; and

a second spacer substantially abutting said interior portion of said die;

wherein said air gap extends between said spacers.

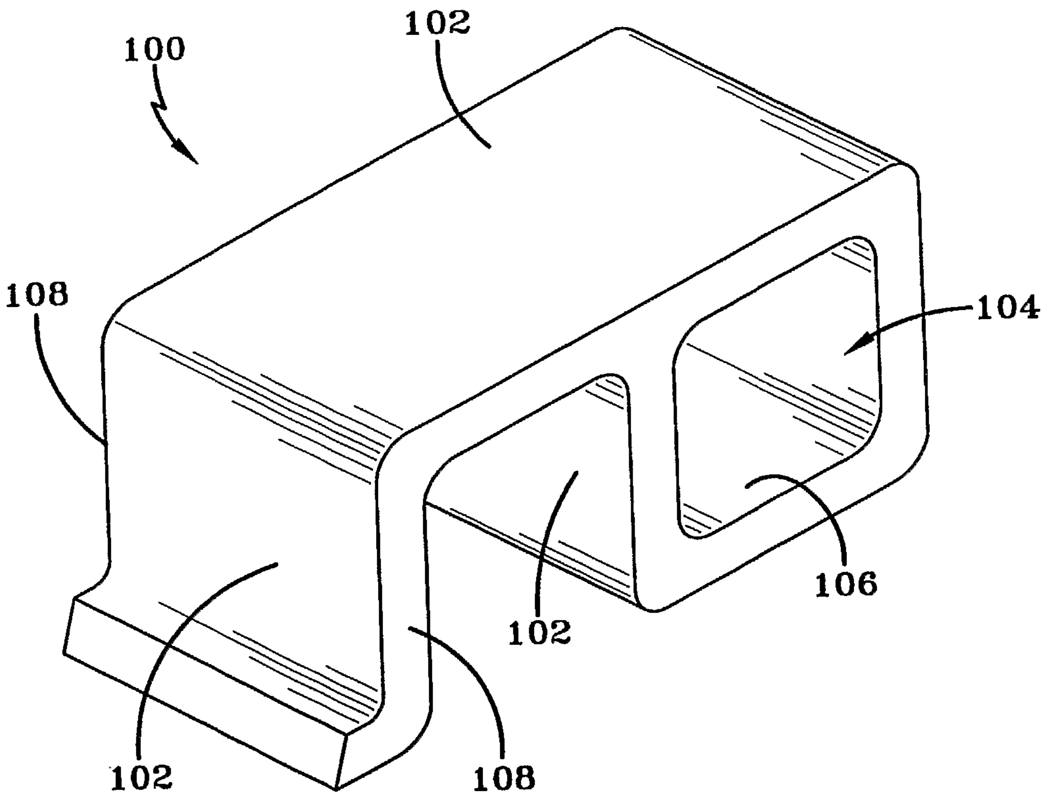


FIG-1

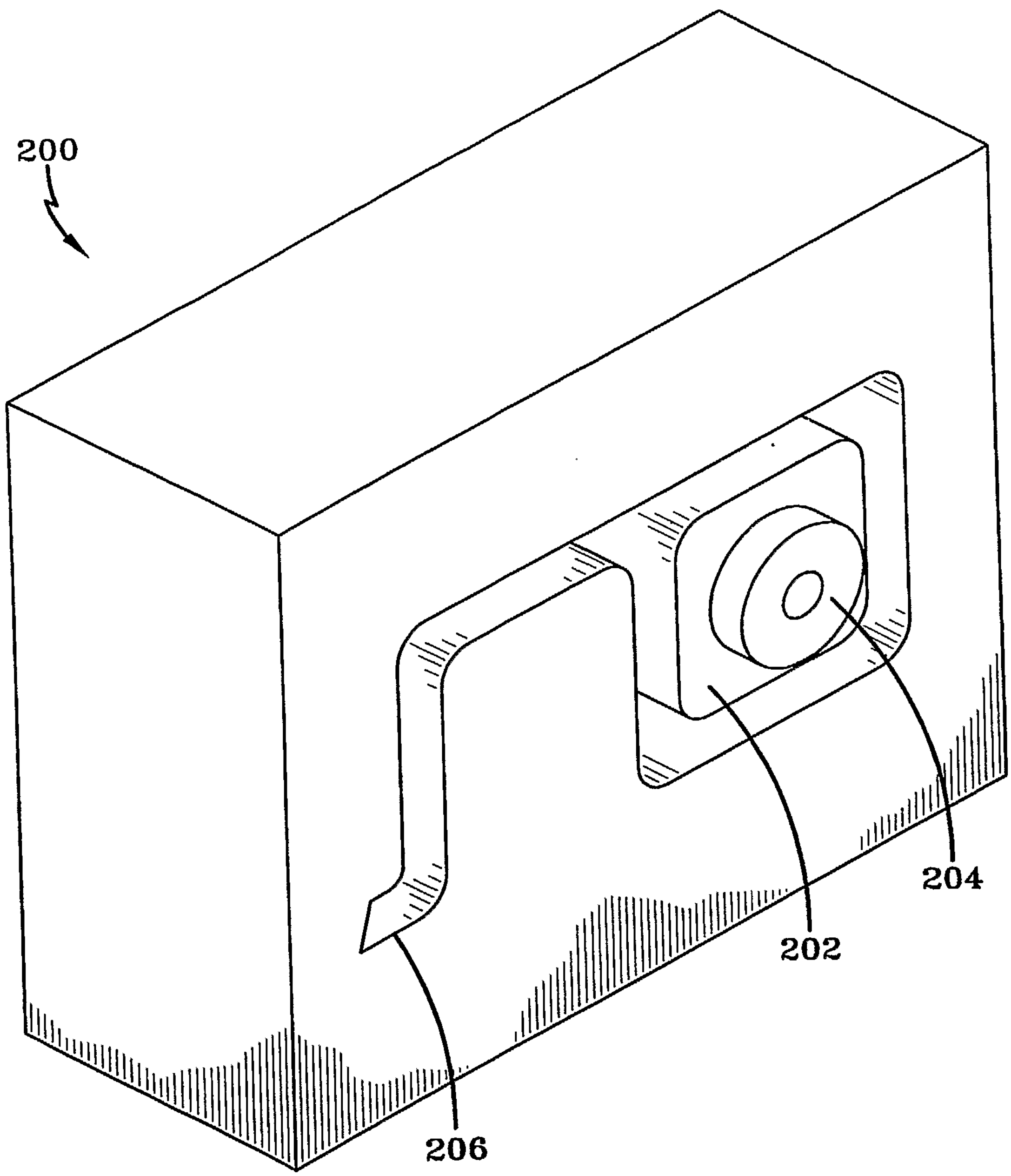


FIG-2

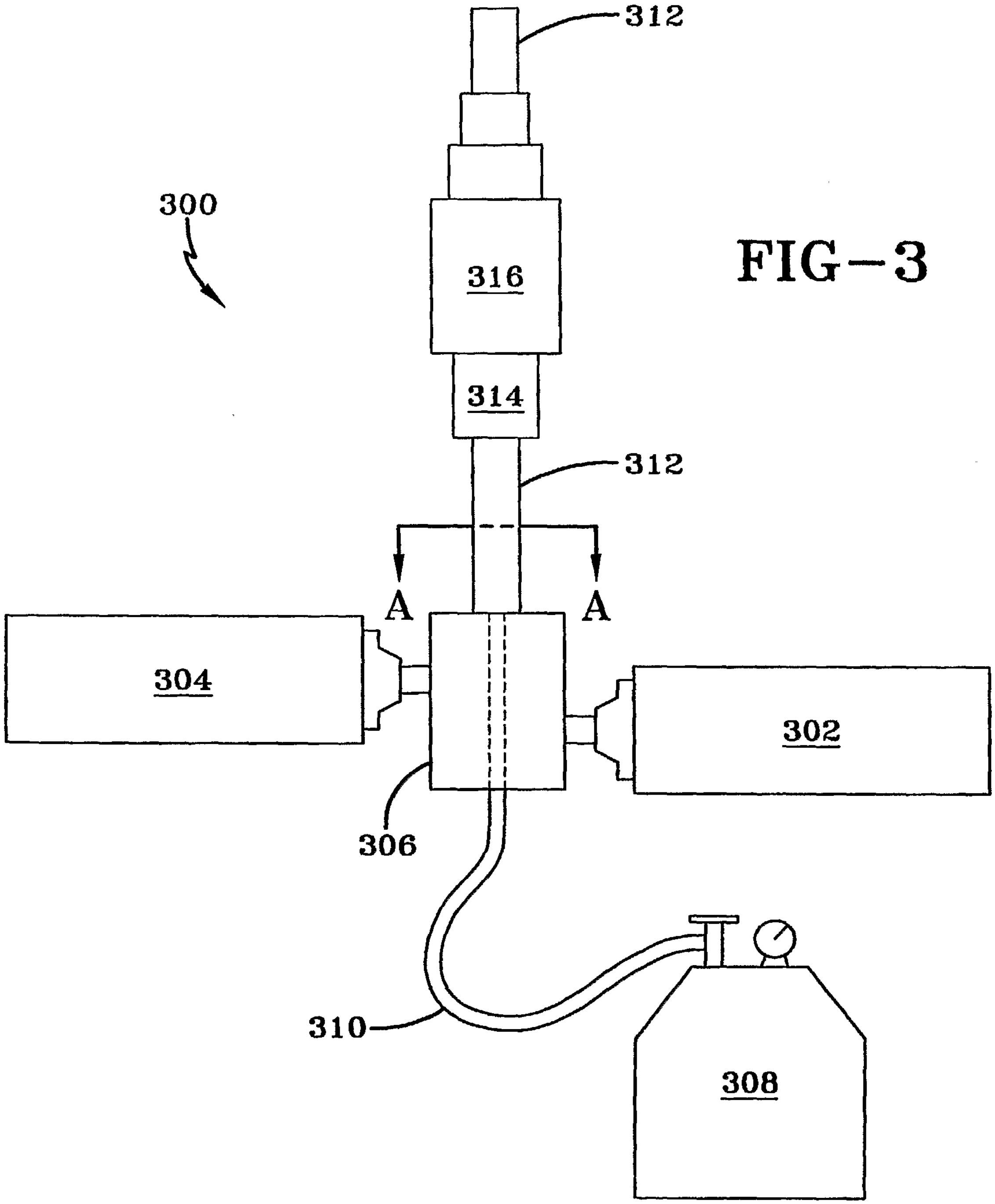


FIG-3

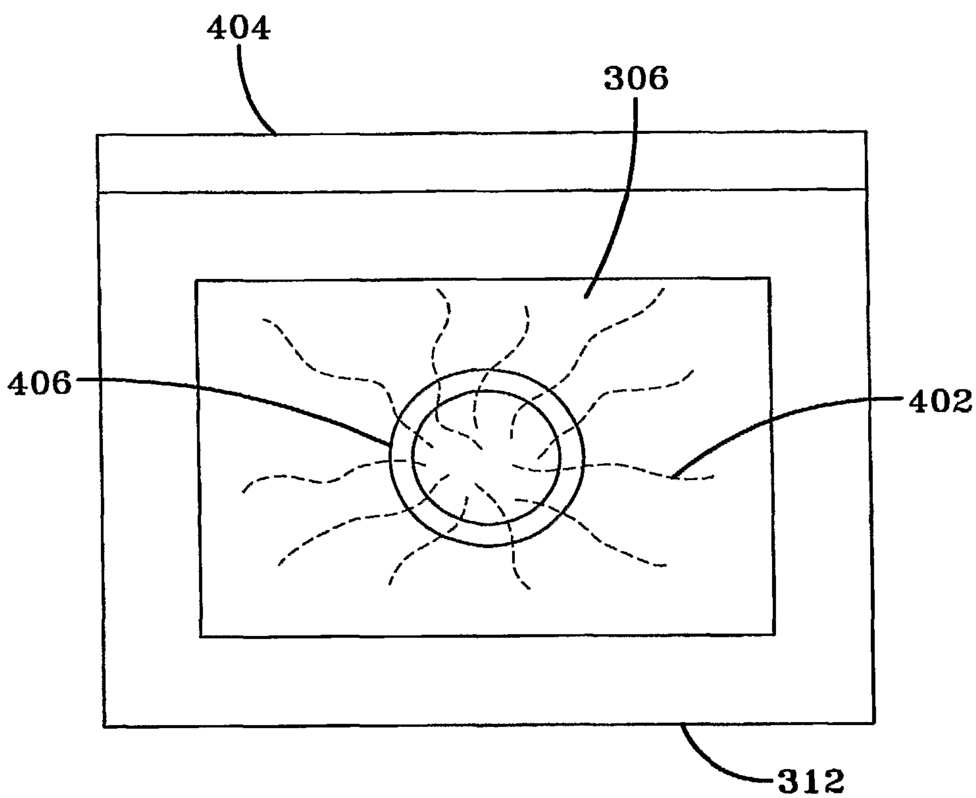


FIG-4

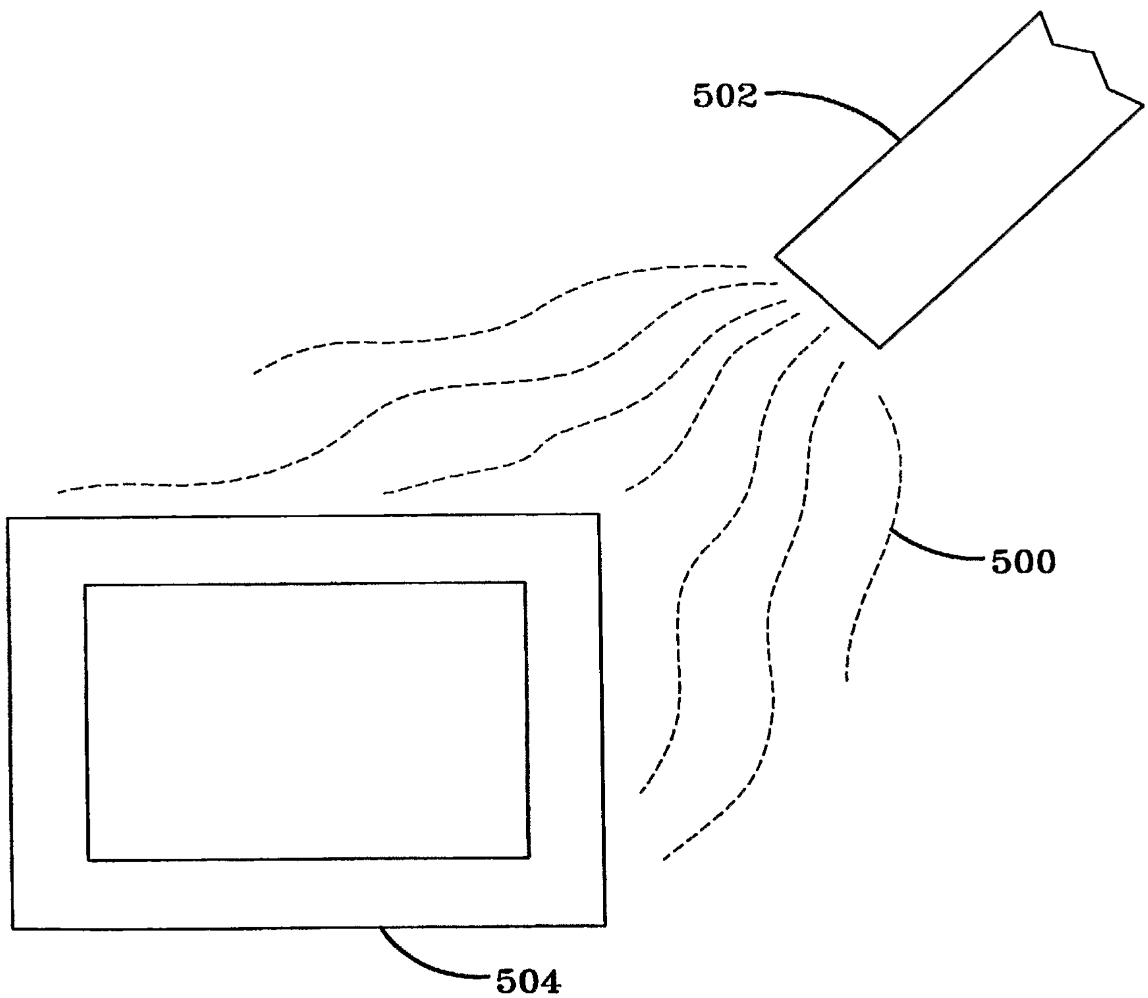
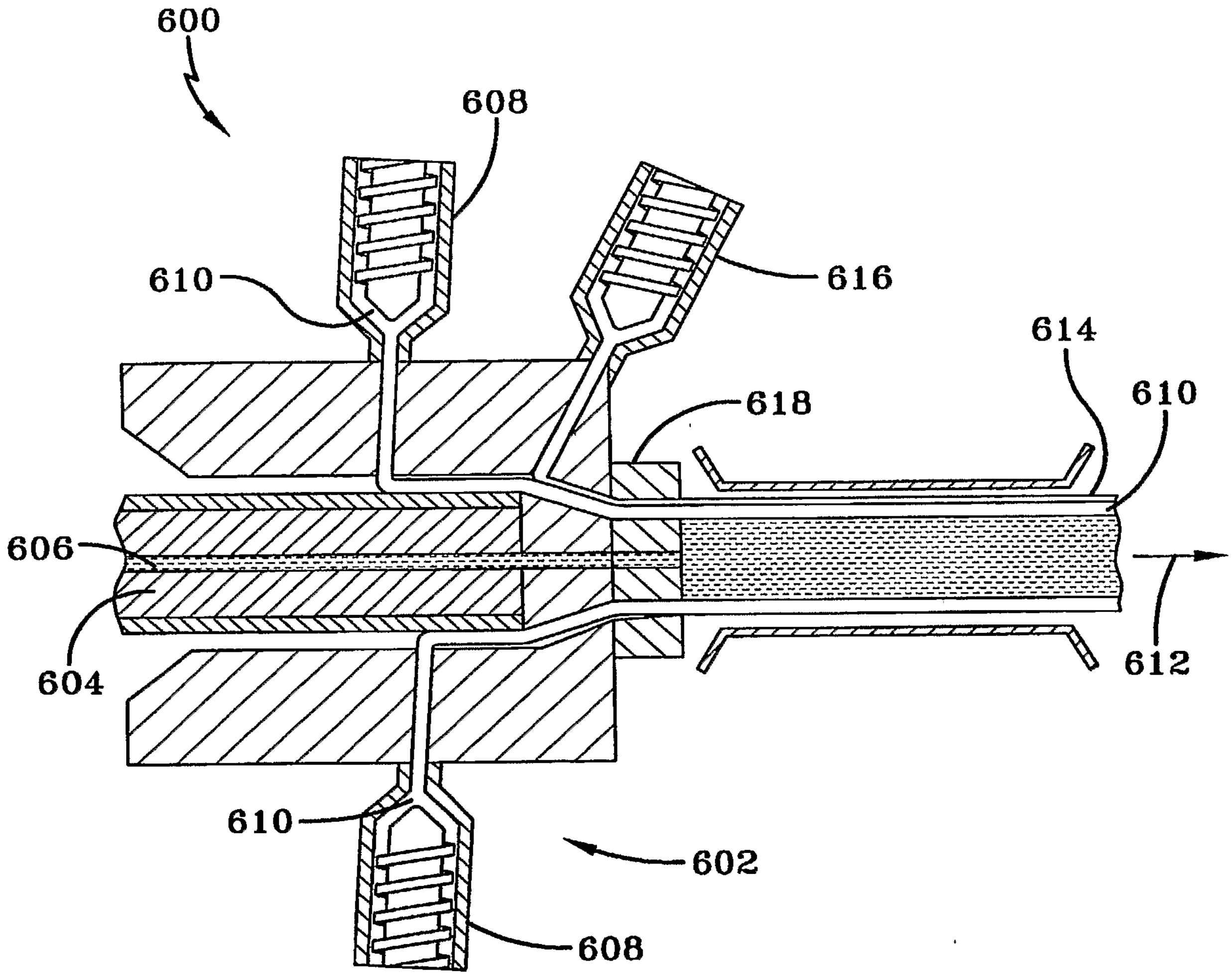


FIG-5



FIG–6

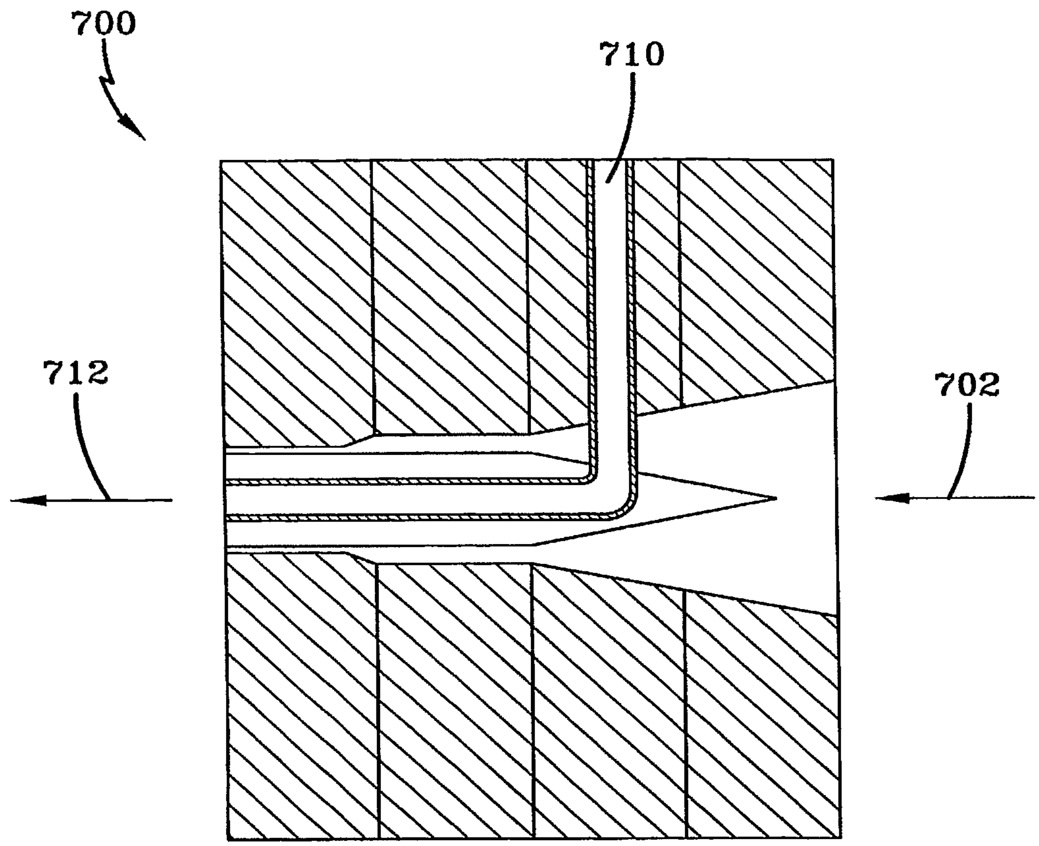


FIG-7

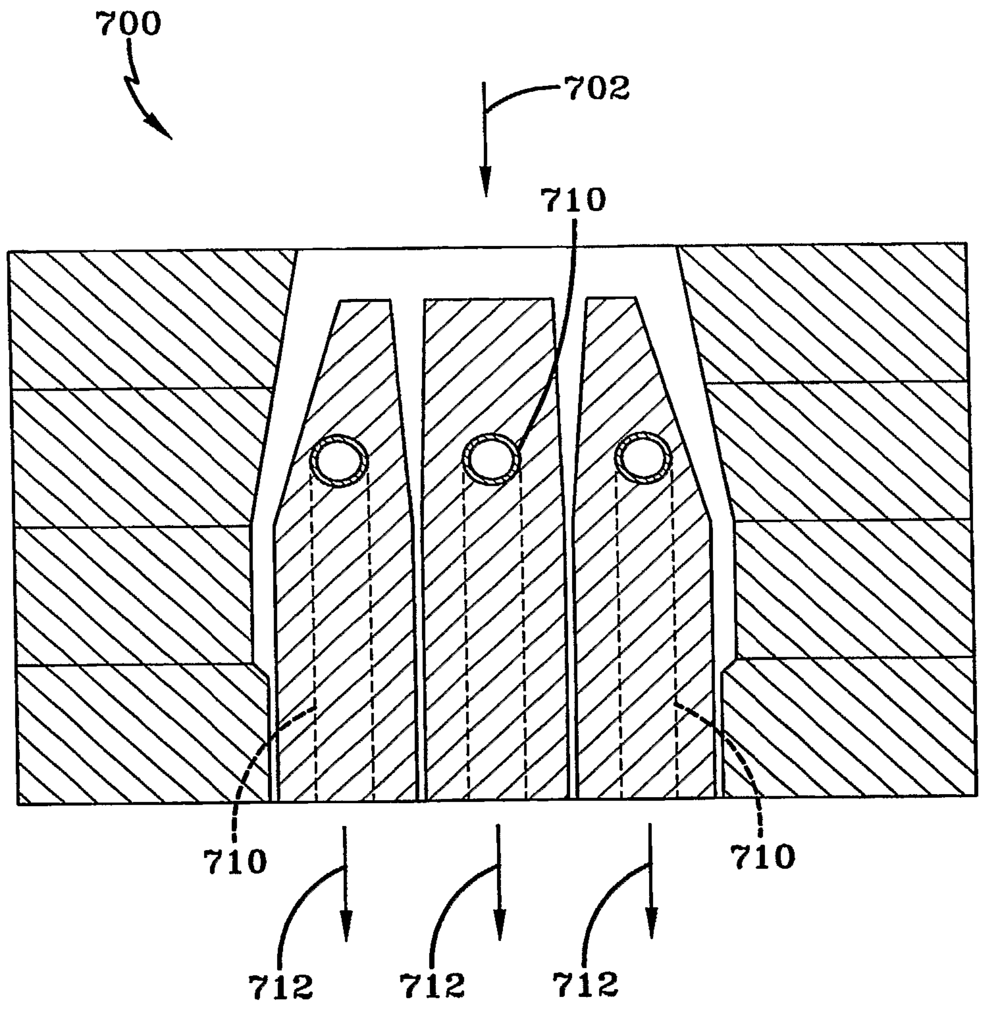


FIG-8

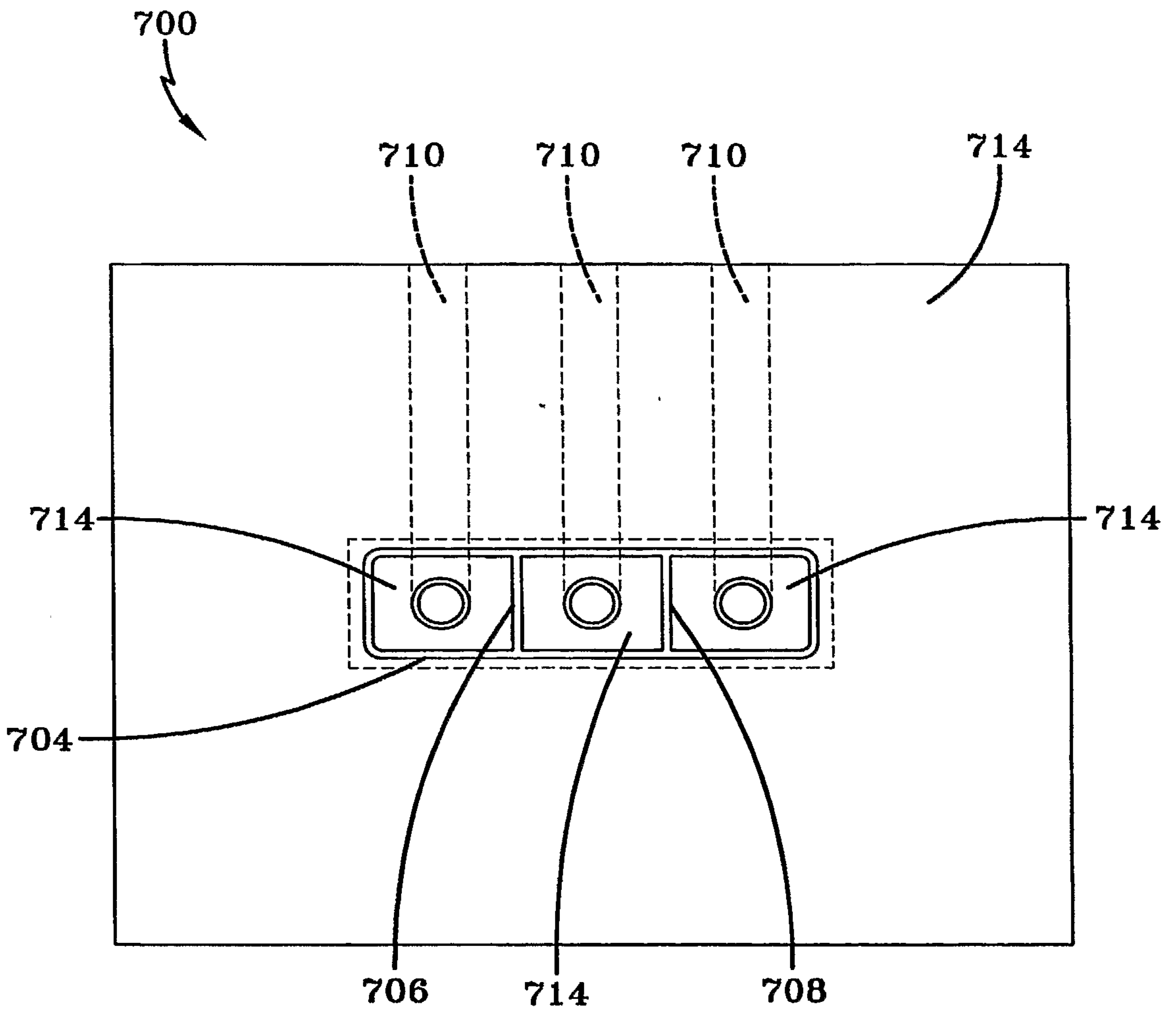


FIG-9

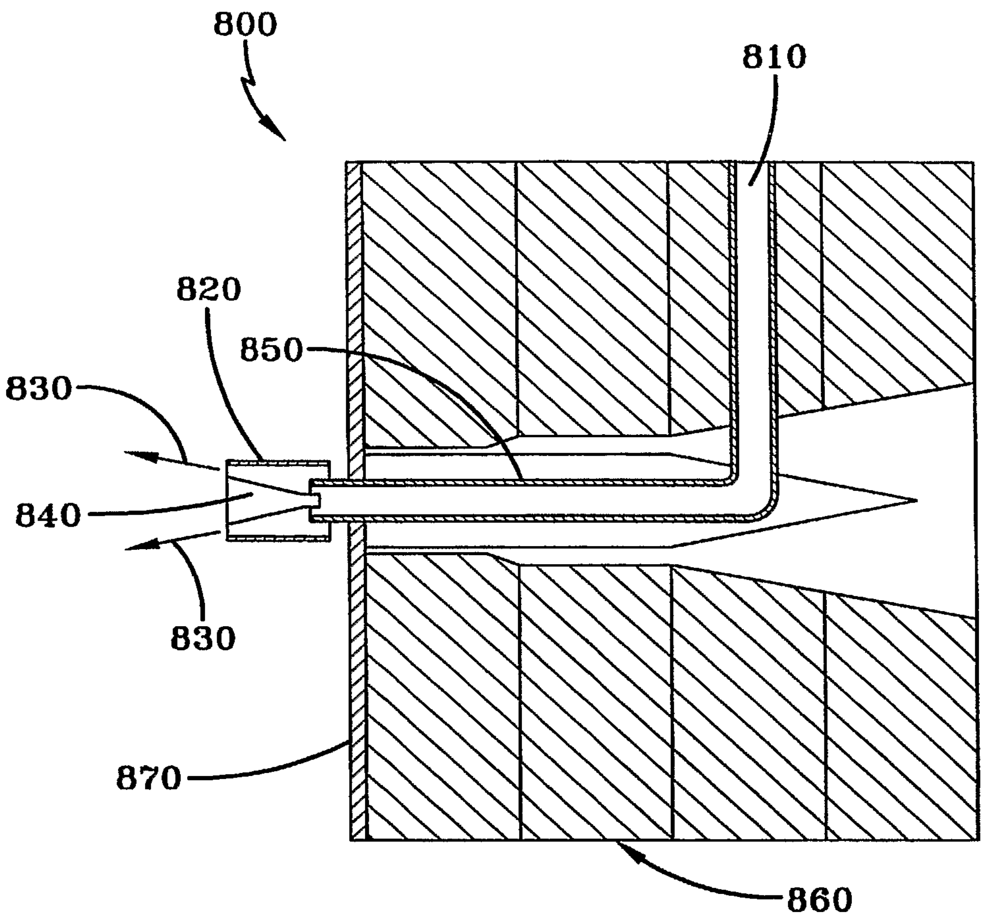


FIG-10

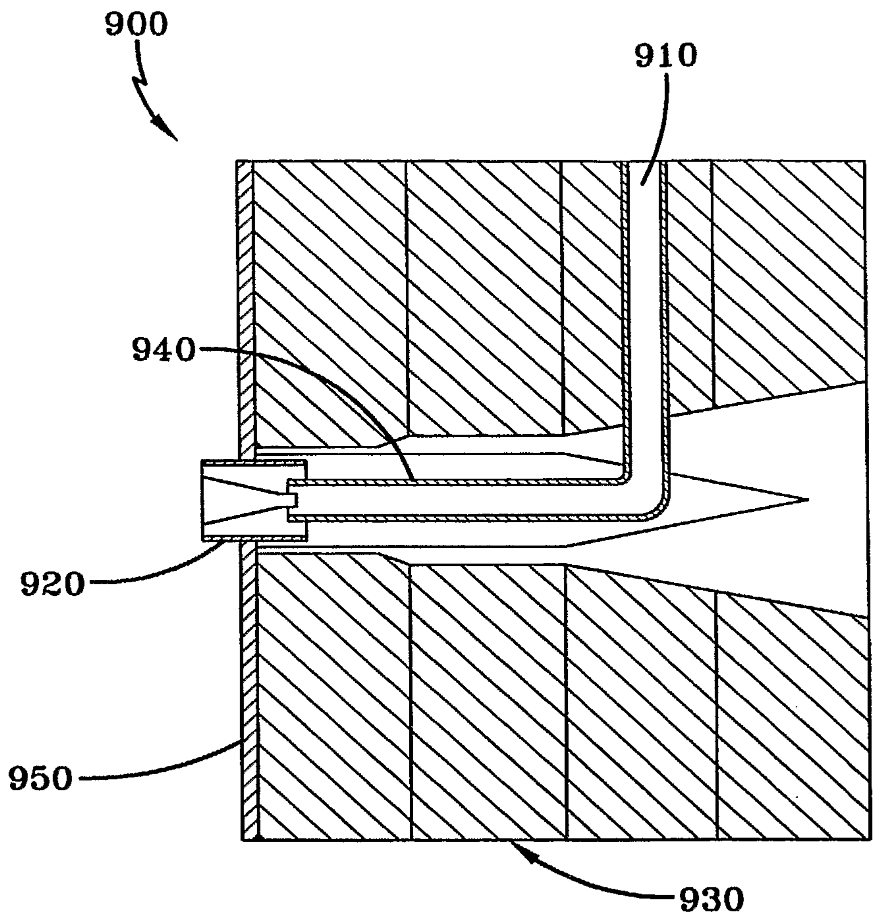


FIG-11

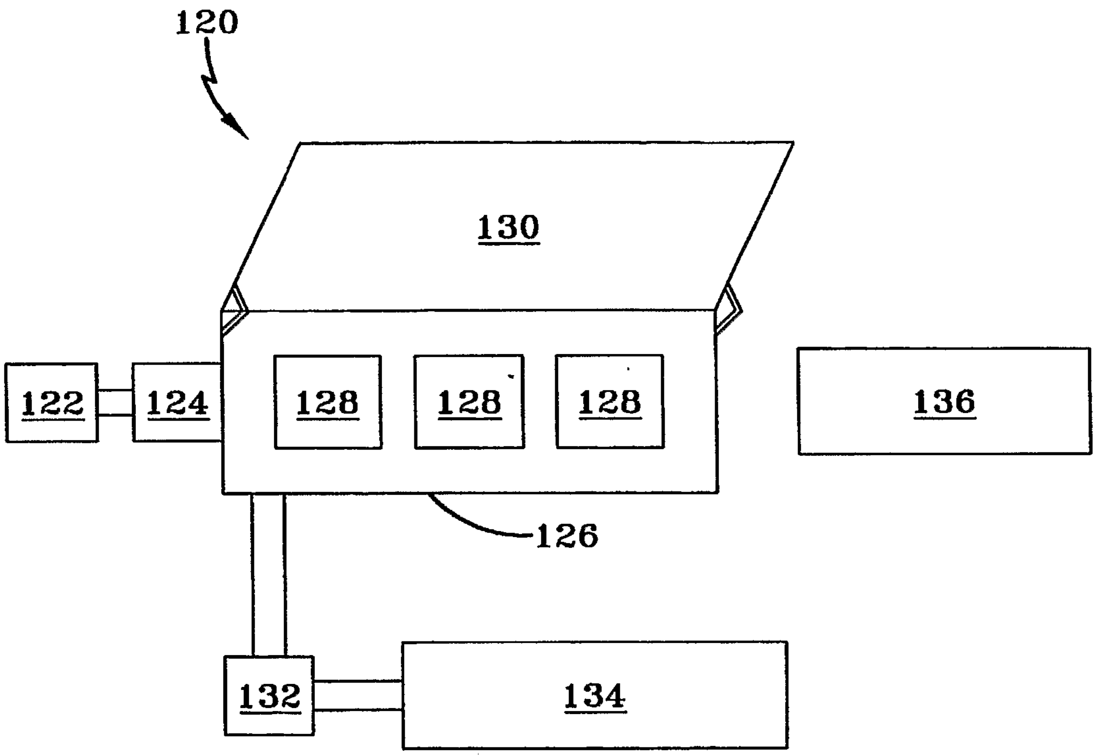


FIG-12

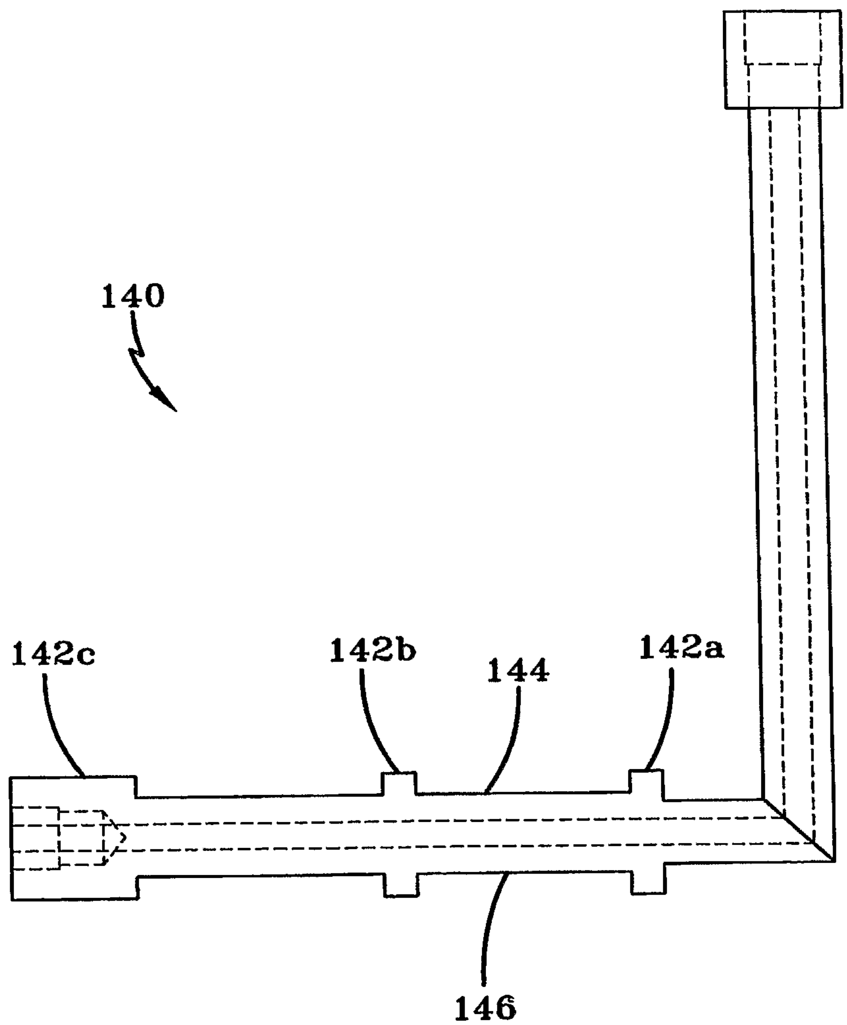


FIG-13

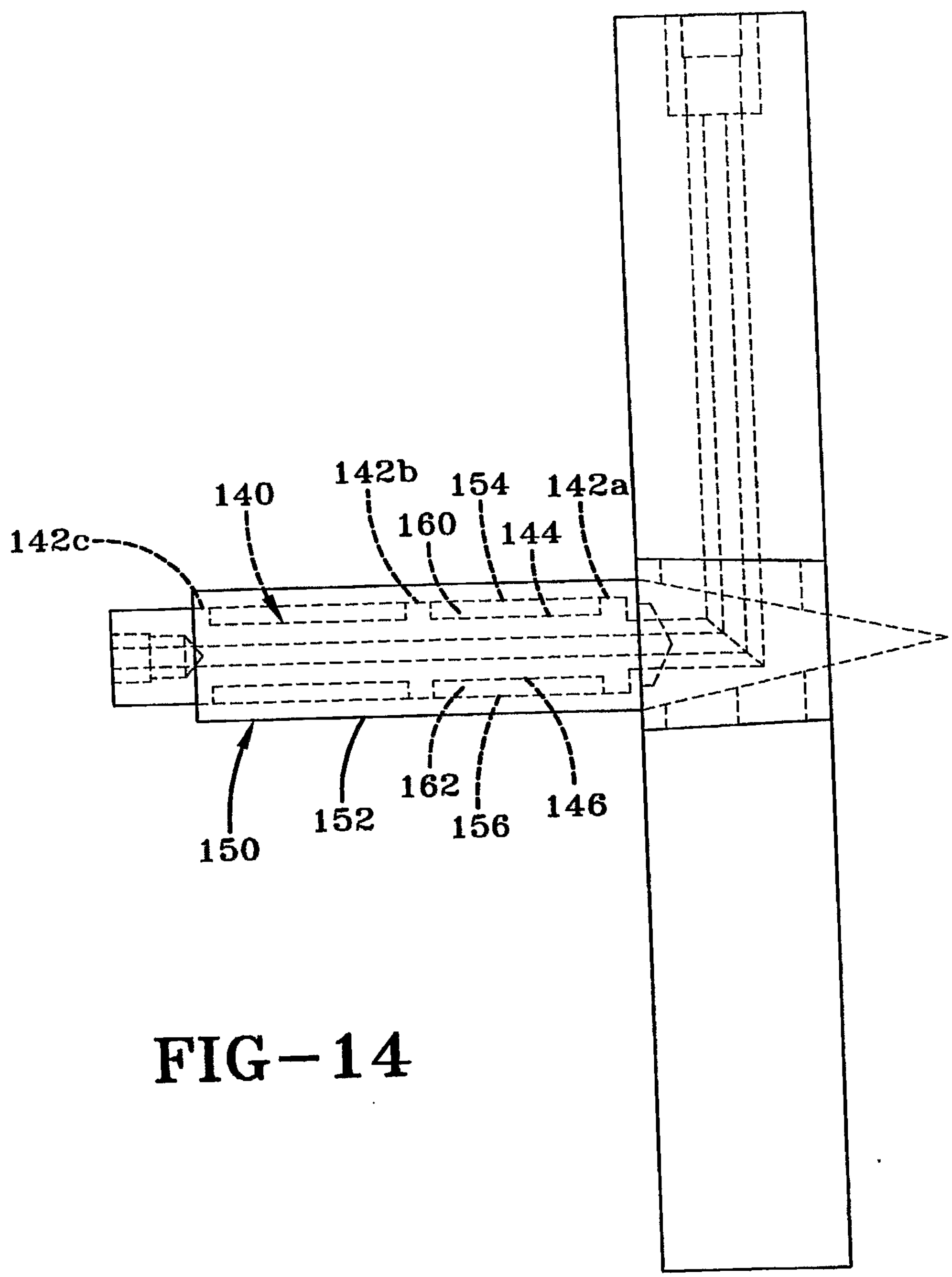


FIG-14